

PhazeComp 2.0

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PhazeComp 2.0 is Zick Technologies' newly updated, state-of-the-art program for compositional phase behavior computations using an equation of state (EOS). It acts as a virtual PVT (pressure-volume-temperature) laboratory and as a vehicle for tuning EOS fluid characterizations. It can simulate practically any single-cell PVT experiment one can imagine (and many multi-cell experiments as well). It will accept, as input, virtually any data that can be measured in such an experiment. It will then adjust (through non-linear, user-weighted, least-squares regression) any user-selected combination of EOS parameters to optimize the predictions of the experimental data.

PhazeComp has always been the most powerful and flexible PVT program available, but now it is even more so, with the introduction of many new and exclusive features in PhazeComp 2.0, including:

- **Plotting.** In conjunction with the open-source software, *gnuplot*, PhazeComp will plot (in PDF format) any experimental quantity against any other, comparing calculated results with experimental data. PhazeComp will also plot phase envelopes (more details below), characterization properties, gamma distributions, and black oil properties.
- **Reporting.** In conjunction with the open-source software, *LaTeX*, PhazeComp will automate the building of a report in PDF format. PhazeComp will generate any number of user-directed tables and figures and lay them out automatically with numbering, captioning, cross-referencing, and hyperlinking. Users will only need to add their own text and rerun LaTeX to produce, within seconds, a professional quality, finished report.
- **Phase Envelopes.** PhazeComp can now generate P-T (pressure versus temperature), P-X (pressure versus molar composition), and P-W (pressure versus mass composition) diagrams. PhazeComp will identify bubble points, dew points, critical points, phase inversions, and incipient phase transitions, along with physical properties at each saturation point. It will cover the entire range from ultra-high vacuum to ultra-high pressure. If plotting is enabled, it will generate any number of user-directed plots, with axes on normal scales, log scales, or inverse temperature scales.
- **Black Oil Tables.** The generation of black oil tables has been enhanced. PhazeComp's standard black oil table (.bot) output file can now include the standard black oil properties, R_s (solution gas-oil ratio), B_o (oil formation volume factor), $1/B_o$, R_v (oil-gas volatility ratio, also known as r_s), B_g (gas formation volume factor), and $1/B_g$. PhazeComp will also calculate the surface oil and gas densities that will optimize the prediction of reservoir oil and gas densities. PhazeComp can also be directed to output the black oil tables to separate files in Eclipse 100 format or in Sensor format. Finally, plots can be generated for all the saturated black oil properties, along with reservoir densities and viscosities.
- **Viscosity Estimates.** The drawback to the industry standard Lohrenz-Bray-Clark (LBC) viscosity correlation is that it is not very predictive for components with a molecular weight greater than about 90. The workaround is to adjust the components' ZcVis parameters (critical z-factors for viscosities) to match viscosity data, but that has never been easy to do in a systematic way. However, PhazeComp now includes a proprietary method for estimating the temperature-

dependent, atmospheric liquid viscosities for each component that would be a liquid at a specified temperature and atmospheric pressure. It will then automatically calculate the value of $Z_c V_{is}$ necessary to reproduce that viscosity. This results in LBC viscosity predictions for reservoir fluids at reservoir conditions that are usually much more accurate (often within 10% of measured values), even before any subsequent tuning.

- **MW/SG vs MW Correlation.** Experience has shown that distillation cuts from multiple samples of related fluids from a reservoir or field will display a linear relationship between MW/SG and MW. That's not surprising, because the molecular weight divided by the specific gravity is essentially the molar volume of a cut, and if the reservoir fluids are made up of similar building blocks, the molar volume should be linear in MW. Therefore, PhazeComp has introduced a new correlation between SG and MW (to augment the previous Søreide and Jacoby correlations). If activated, it will calculate SG versus MW from a linear relationship between MW/SG and MW. By default, the linear model will closely reproduce the Katz-Firoozabadi SG vs MW correlation, but the two parameters of the linear model can be adjusted to match available data.
- **Gamma Fitting.** In addition to fitting (or modeling) MWs, component mole fractions, or component mass fractions, a Gamma distribution can now be fit to the logarithms of the component mole or mass fractions. This can improve the fitting of the tail end of a distribution, where the mole or mass fractions become very small (if they are still deemed significant and reliable). Gamma distributions can now also be plotted, comparing the input molar or mass distribution with the model distribution.

As always, PhazeComp will perform all the calculations expected of a petroleum engineering PVT program, including the simulation of all standard PVT experiments, the prediction of gravity-induced compositional gradients, and the generation of phase envelopes, black oil PVT tables, and plots. It will use any of the industry standard cubic equations of state and will easily interface with other industry standard software, such as reservoir simulators. These capabilities are not unusual, but PhazeComp also has many *unique* features, which include:

- PhazeComp acts as a virtual PVT laboratory. All calculations (including PVT experiments, flash and saturation point calculations, fluid mixing, etc.) are performed in a precise, user-specified order. The temperatures, pressures, and compositions generated in one calculation can be saved, manipulated, and then used in subsequent calculations.
- Nonstandard PVT experiments can easily be defined. At each stage of an experiment, the temperature, pressure and composition can be altered before equilibration. After equilibration (which is achieved through a flash or saturation point calculation), some or all of either equilibrium phase can be removed. Any number of properties from a list of hundreds (including bulk, compositional, intrinsic, and extrinsic), from before or after fluid removal, can be input as experimental data and/or requested as output. Any set of units can be specified for any of the properties.
- Minimum miscibility pressures and solvent enrichment levels (MMPs and MMEs) can be calculated by a thermodynamically rigorous, multi-cell, multi-contact algorithm. This proprietary algorithm calculates the correct MMP or MME, regardless of mechanism (condensing, vaporizing, or condensing/vaporizing).
- Any or all equilibrium calculations can be tested for the presence of three-phase or multiple two-phase solutions. When characterizing fluids for reservoir simulation, it is highly desirable to

detect and avoid the possibility of such solutions, since they usually lead to severe stability and convergence problems.

- Multiple fluid characterizations can be used simultaneously. Measured compositions may have their own characterizations (with single carbon-number components up to C7+, C10+, or C30+, for example), while the desired fluid model will usually be characterized with *pseudocomponents*. Each characterization can be based upon a parent characterization, so it can be updated automatically if the parent is modified. PhazeComp will allow each fluid to be input in its native characterization and automatically converted to whichever characterization is used for the phase behavior computations.
- Component properties can be initialized manually, with library values, and/or through accepted correlations. Acentric factors and volume shift factors can be calculated automatically from component boiling points and specific gravities, respectively (or vice versa). Atmospheric liquid viscosities at a specified temperature can be entered or estimated from a proprietary correlation, and ZcVis parameters can be calculated automatically to match those viscosities.
- Any number of fluid samples can be handled simultaneously. Samples can be defined (by name) in a variety of different ways. Fluids can be mixed together or split apart to form new fluids. Fluids can also be produced by one PVT calculation or experiment and then used in another.
- Fluid components can be split or pseudoized automatically, as needed, according to user-specified rules. A four-parameter Gamma distribution model is available for component splitting. The Gamma parameters can be unique to each fluid, or shared among different fluids.
- Any number of named *variables* can be defined by the user and adjusted (within user-specified bounds) by regression. Each variable can be used to modify (through multiplication, division, addition, subtraction, or replacement) any number of EOS parameters, viscosity parameters, Gamma parameters, temperatures, pressures, or fluid compositions. Each parameter, in turn, can be modified by any number of variables. This gives PhazeComp unparalleled power and flexibility in tuning EOS fluid characterizations.
- Problem size is limited only by available computer memory. PhazeComp does not restrict the number of characterizations, components, fluids, experiments, variables, or anything else.
- At the user's direction, PhazeComp can now plot almost anything it can calculate. The plots are in PDF format and exhibit professional quality.
- At the user's direction, PhazeComp can now generate (within seconds) professional quality reports in PDF format. The reports contain PhazeComp-generated tables and figures, all numbered, captioned, cross-referenced, and hyperlinked. Users can easily add their own text to the input files for these reports and generate perfectly structured final documents (which could number in the hundreds of pages), without all the painfully hard work of creating and including the desired graphics. This is one of PhazeComp's new and most exclusive features.
- PhazeComp's user interface is any combination of text editors, spreadsheet programs, gnuplot, LaTeX, and PDF viewers. PhazeComp's free-format, text-only input files can easily be built or edited by these more familiar programs. The structured, text-only output can easily be copied or exported to these other programs for further manipulation, plotting, and reporting purposes, but now PhazeComp can automate the plotting and reporting. PhazeComp's input files consist of user-controlled sequences of commands and data tables, all with a forgiving and easy-to-remember vocabulary and syntax. Input files can *include* other input files, allowing a structured hierarchy of commands and data. Tables (for characterizations and PVT experiments) can be

arranged in any order and even split into multiple sections. They can usually be copied directly from an electronic version of a lab report, with only the headings to be replaced by the appropriate keywords. Experience has shown that there is no quicker or more powerful method of building or editing a complicated sequence of instructions for a PVT program.

- PhazeComp performs all EOS calculations to the limits of machine precision. No other PVT program can boast such accuracy (especially near critical points). PhazeComp will take on all challengers in terms of speed and robustness as well.

PhazeComp is the culmination of more than 40 years of experience in writing EOS and PVT software. Zick Technologies is confident that the program of choice for the industry's true PVT experts will be PhazeComp.